ROCKETS

MODULE 4

WRITTEN BY
JEFFREY D. MONTGOMERY

DESIGN AND ILLUSTRATIONS
Peggy P. Greenlee

EDITING
Teresa Y. Hammer

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LEARNING OUTCOMES

Chapter 1 - History of Rockets

After completing this chapter, you should be able to:
- Identify historical facts about the Greeks, Chinese and British, and their roles in the development of rockets.
- Describe America's early contributions to the development of rockets.
- List the early artificial and manned rocket launches and their missions.

Chapter 2 - Rocket Principles

After completing this chapter, you should be able to:
- Define acceleration.
- Define inertia.
- Define thrust.
- Describe Newton's First Law of Motion.
- Describe Newton's Second Law of Motion.
- Describe Newton's Third Law of Motion.

Chapter 3 - Rocket Systems and Controls

After completing this chapter, you should be able to:
- Identify the four major systems of a rocket.
- Describe the purpose of each of the four major systems of a rocket.
- Define payload.

History of Rockets

Important Terms

Neil Armstrong - first man to walk on the Moon
Roger Bacon - increased the range of rockets
Wernher von Braun - director of the V-2 rocket project
William Congreve - designed rockets for military use
Jean Froissart - improved the accuracy of rockets by launching them through tubes
Yuri Gagarin - a Russian; the first man in space
John Glenn - first American to orbit the Earth
Robert Goddard - experimented with solid and liquid propellant rockets; is called the Father of Modern Rocketry
William Hale - developed spin stabilization
Hero - developed first rocket engine
Sergei Korolev - the leading Soviet rocket scientist
Sir Isaac Newton - laid scientific foundation for modern rocketry with his laws of motion
Hermann Oberth - space pioneer; wrote a book about rocket travel into outer space
Alan Shepard - first American in space
Skylab **-** first US space station
Space Shuttle - a space transportation system for traveling to space and back to Earth
Sputnik **I -** first artificial satellite
Konstantin Tsiolkovsky - proposed the use of rockets for space exploration

Today's rockets are remarkable examples of scientific research and experimentation over thousands of years. Let's take a moment and recall some of the fascinating rocket developments of the past. We have also included some activities to help clarify and amplify the information.

HISTORY

The history of rockets began around 400 BC when a Greek named Archytas built a flying wooden pigeon. It was suspended on a wire and propelled by escaping steam. About 300 years later, another Greek, **Hero** developed the first rocket engine.

It was also propelled by steam. Hero placed a sphere on top of a pot of water. The water was heated and turned into steam. The steam traveled through pipes into the sphere. Two L-shaped tubes on opposite sides of the sphere allowed the gas to escape. This created a thrust that caused the sphere to rotate. This device is known as a Hero Engine.

See Activity One - The Hero Engine
Refer to the Activity Section at the end of the chapter for this activity.

In the first century AD, the Chinese developed a form of gunpowder and used it as fireworks for religious and festive celebrations. The Chinese began experimenting with the gunpowder-filled tubes. They attached bamboo tubes to arrows and launched them with bows.

Fireworks and rockets share a common heritage.

Early Chinese Rocket

In 1232, with the Chinese and Mongols at war with each other, these early rockets were used as arrows of flying fire. This was a simple form of a solid-propellant rocket. A tube, capped at one end, contained gunpowder. The other end was left open and the tube was attached to a long stick. When the powder ignited, the rapid burning of the powder produced fire, smoke and gas that escaped out the open end and produced a thrust. The stick acted as a guidance system that kept the rocket headed in one general direction as it flew through the air. Records indicate that from this point, the use of rockets spread.

Rocket experiments continued throughout the 13^{th} to 15^{th} centuries. In England, **Roger Bacon** improved the forms of gunpowder, which increased the range of the rocket. In France, **Jean Froissart** achieved more accuracy by launching rockets through tubes. This idea was the forerunner of the bazooka.

During the latter part of the 17^{th} century, **Sir Isaac Newton** laid the scientific foundations for modern rocketry when he developed his laws of motion. These laws explain how rockets work and are discussed in detail in Chapter 2 of this volume.

Newton's laws of motion influenced the design of rockets. Rocket experimenters in Germany and Russia began working with very powerful rockets. Some of these rockets were so powerful that their escaping exhaust flames bored deep holes in the ground even before liftoff.

At the end of the 18^{th} century, **Colonel William Congreve**, an artillery expert with the British military, set out to design rockets for military use. His rockets increased the rocket's range from 200 to 3,000 yards and were very successful in battle, not because of accuracy, but because of the sheer numbers that could be fired. During a typical siege, thousands of rockets could be fired. These became known as the Congreve rockets, and were the rockets that lit the sky during the battle at Fort McHenry in 1812, while Francis Scott Key wrote his poem. The poem later became our national anthem, "The Star Spangled Banner."

Even with Congreve's work, the accuracy of rockets still had not improved much. So, rocket researchers all over the world were experimenting with ways to improve accuracy. An Englishman, **William Hale**, developed a technique called spin stabilization. In this method, the escaping exhaust gases struck small vanes at the bottom of the rocket, causing it to spin much as a bullet does in flight. Many rockets still use variations of this principle today.

Congreve Rocket

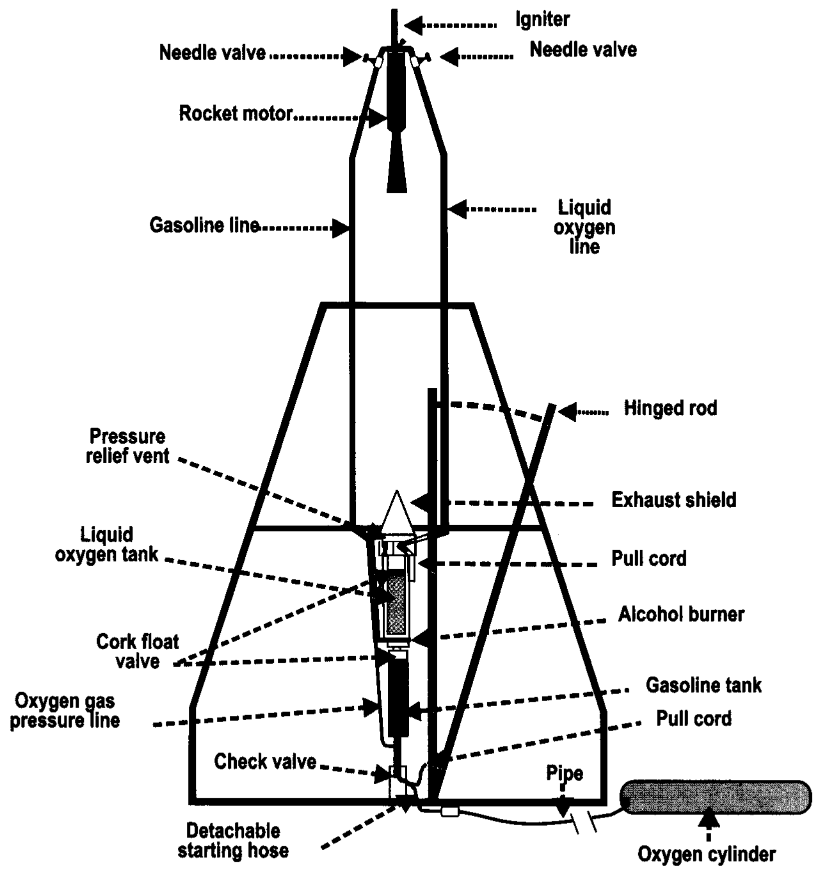
See Activity Two - Congreve Rocket
Refer to the Activity Section at the end of the chapter for this activity.

MODERN ROCKETRY

In 1898, a Russian schoolteacher, **Konstantin Tsiolkovsky**, proposed the idea of space exploration by a rocket. He published a report in 1903 suggesting the use of liquid propellants for rockets in order to achieve greater range. Tsiolkovsky stated that only the exhaust velocity of escaping gases limited the speed and range of a rocket. For his ideas, research and vision, Tsiolkovsky has been called the <u>father of modern astronautics</u>.

Dr. Robert H. Goddard

Early in the 20th century, an American physics professor, **Dr. Robert H. Goddard** conducted many practical experiments with rockets. His research led to major breakthroughs in the development of rockets. His earliest experiments were with solid-propellant rockets. Then he became convinced that liquid fuel would better propel a rocket.

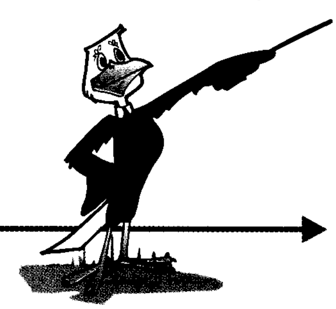


Dr. Goddard's First Liquid Propellant Rocket

In 1926, Goddard achieved the first successful flight with a liquid-propellant rocket. It was fueled by liquid oxygen and gasoline. This was the forerunner of today's rockets.

As he continued with his experiments, his liquid-propellant rockets grew bigger and flew higher. He also developed a gyroscope system for flight control, a payload compartment and a parachute recovery system. Additionally, he believed that multistage rockets were the answer for achieving high altitudes. For his many accomplishments, Dr. Goddard is known as the **<u>father of modern rocketry</u>.**

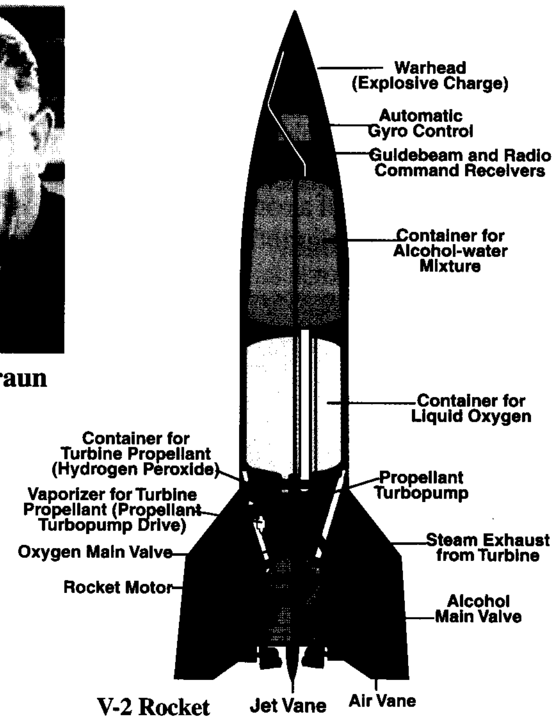
See Activity Three - Balloon Staging
Refer to the Activity Section at the end of the chapter for this activity.



In 1923, **Hermann Oberth** of Germany, published a book about rocket travel into outer space. Because of his writings, small rocket societies were started around the world. In Germany, one such society, the Society for Space Travel, led to the development of the V-2 rocket.

Wernher von Braun

The V-2 rocket with its explosive warhead was a formidable weapon which could devastate whole city blocks. Germany used this weapon against London during World War II, but fortunately this occurred too late in the war to change the outcome. The V-2 was built under the directorship of **Wernher von Braun**, who, after the war, headed up the US' rocket program.



V-2 Rocket

With the fall of Germany, the Allies captured many unused V-2 rockets and components. Many German rocket scientists came to the United States. Others went to the Soviet Union. Von Braun and about 120 of his scientists signed contracts to work with the US Army. Von Braun and his team used captured V-2s to teach American scientists and engineers about rocketry.

In the Soviet Union, **Sergei Korolev** was leading Russian scientists in rocket development. He organized and led the first successful Soviet intercontinental ballistic missile in August 1957 and was getting ready to launch the world's first satellite. He is considered to be the father of the Soviet space program.

Space Race

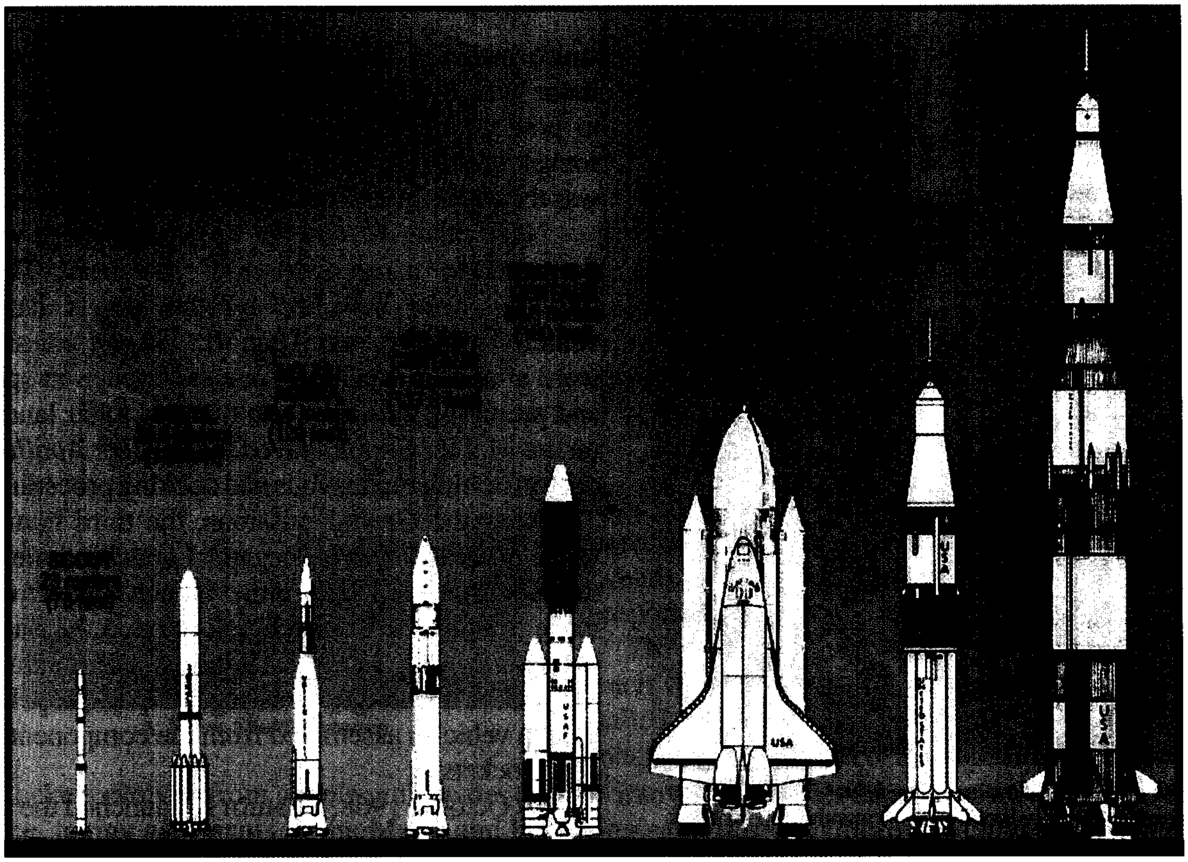
Both the United States and the Soviet Union recognized the potential of rocketry as a military weapon and began a variety of experimental programs. The United States began a program of high-altitude atmospheric sounding rockets . Then the US developed a variety of medium - and long-range intercontinental ballistic missiles. These became the starting points for the US space program.

Missiles such as the Redstone, Atlas and Titan would eventually launch satellites and astronauts into space. Collectively, they were called rocket launch vehicles, and they were the real workhorses for the space program.

A launch vehicle is the rocket system that lifts the spacecraft. It gives the spacecraft enough force to reach orbit. These launch vehicles propelled people and cargo into space. The diagram on the next page shows the rocket launch vehicle family used by the US space program.

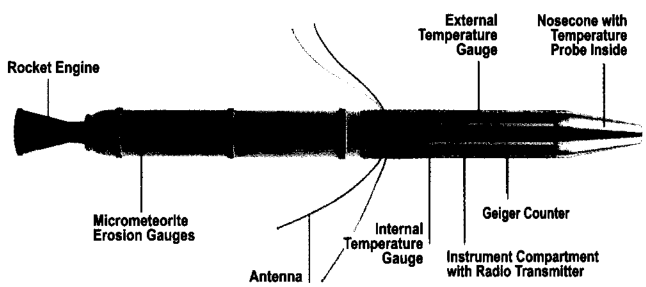
On October 4, 1957, the Soviet Union launched the first artificial (man-made) satellite, ***Sputnik* I,** into space. The race for space between the two superpowers, the US and the USSR, had begun.

On January 31, 1958, the US launched ***Explorer* I**. Then, in October 1958, the US formally organized its space program by creating the National Aeronautics and Space Administration (NASA). NASA became the civilian agency with the goal of peaceful exploration of space for the benefit of all humankind. The Department of Defense (DoD) became responsible for research and development in the area of military aerospace activities.



The United States Rocket Launch Vehicles

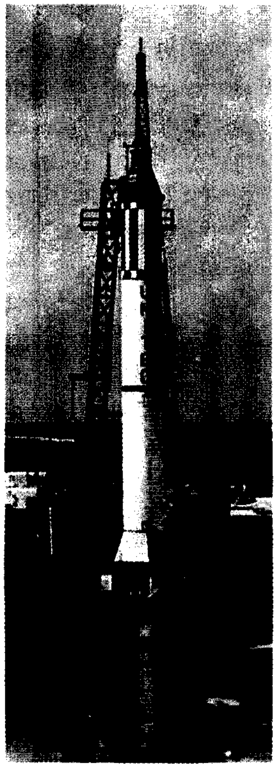
Sputnik I



Explorer I.

Now, the US began to study space exploration in earnest. Both the US and the Soviet Union were sending many people and machines into space. In April of 1961, a Russian named **Yuri Gagarin**, became the first man to orbit Earth. Then, in less than a month later, **Alan Shepard**, aboard his *Mercury* capsule, Freedom 7, became the first American in space. The Redstone rocket that propelled Shepard was not powerful enough to place the *Mercury* capsule into orbit. So, the flight lasted only 15 minutes and reached an altitude of 187 kilometers. Twenty days later, even though the Soviet Union was ahead of the US in the space race, President John F. Kennedy announced the objective of putting a man on the Moon by the end of the decade.

In February 1962, **John Glenn** became the first American to orbit the Earth aboard the *Mercury* capsule, Friendship 7. Glenn was launched by the more powerful Atlas rocket and remained in orbit for 4 hours and 55 minutes.



Alan Shepard's *Mercury* capsule atop a Redstone rocket.

John Glenn's *Mercury* capsule atop an Atlas launch vehicle.

The US then began an extensive unmanned space program aimed at supporting the manned lunar landing program. The Atlas rocket continued to power these missions until the larger Centaur rocket replaced it. As rocket building was refined, so was the capability of the US to explore the Moon.

Next came the *Gemini* missions, which were designed to carry two crew members. These missions were launched by the largest launch vehicle available, the Titan II. *Gemini* missions were aimed at expanding our experience in space and preparing the U.S. for a manned lunar landing on the Moon. *Gemini* paved the way for *Apollo* by demonstrating rendezvous and docking procedures.

After the *Gemini* missions, the third manned space program, *Apollo*, began. Launching men to the Moon required much larger launch vehicles than those available. So, the US developed the Saturn launch vehicles; Saturn I, IB, and V. The Saturn I and IB were large two-stage liquid-propellant launch vehicles assembled from the components of other rockets.

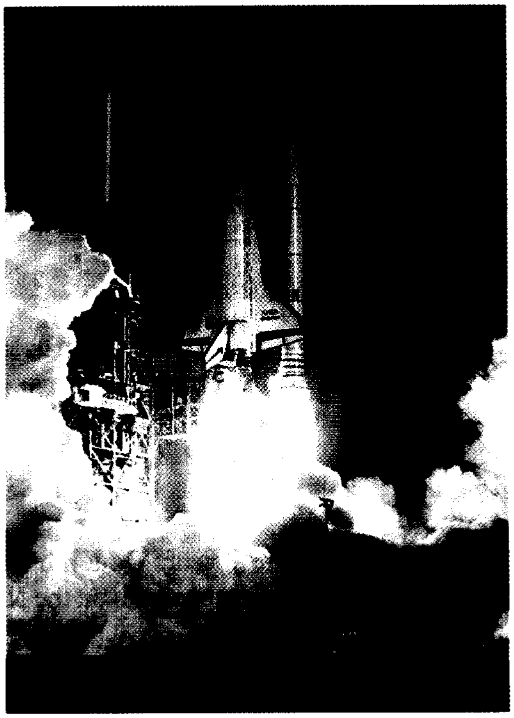
In October 1968, a Saturn IB launched the first three-person mission, *Apollo* 7. Then, the three-stage Saturn V was developed with one goal — send humans to the Moon. On July 20, 1969, *Apollo 11* landed on the Moon, powered by the Saturn V launch vehicle, and **Neil Armstrong** became the first man to walk on the Moon.

Neil Armstrong's photo of Buzz Aldren planting the U.S. Flag on the Moon.

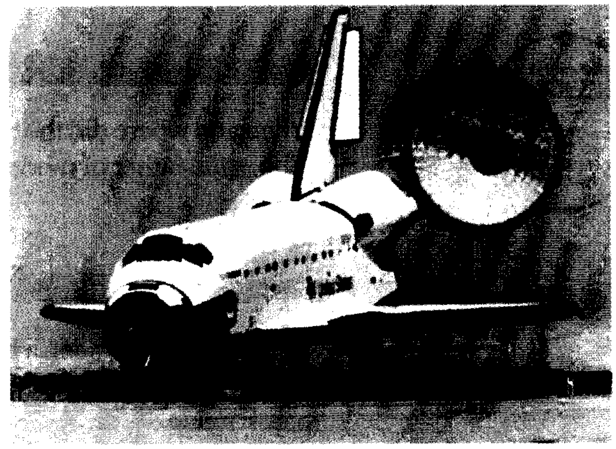
The United States' next project was ***Skylab*** - the US' first space station. The Saturn IB launch vehicle was used again for *Skylab*. *Skylab* was launched in May 1973 and had three separate missions between 1973 and 1974. The last mission was the longest. It lasted 84 days.

Skylab in orbit over the Amazon River in Brazil.

After the space station, the US concentrated on a reusable launch system, the Space Shuttle. The shuttle used solid rocket boosters and three main engines on the orbiter to launch. The reusable boosters fall off about two minutes into the flight. Parachutes deploy to decelerate the solid



A Space Shuttle Launch

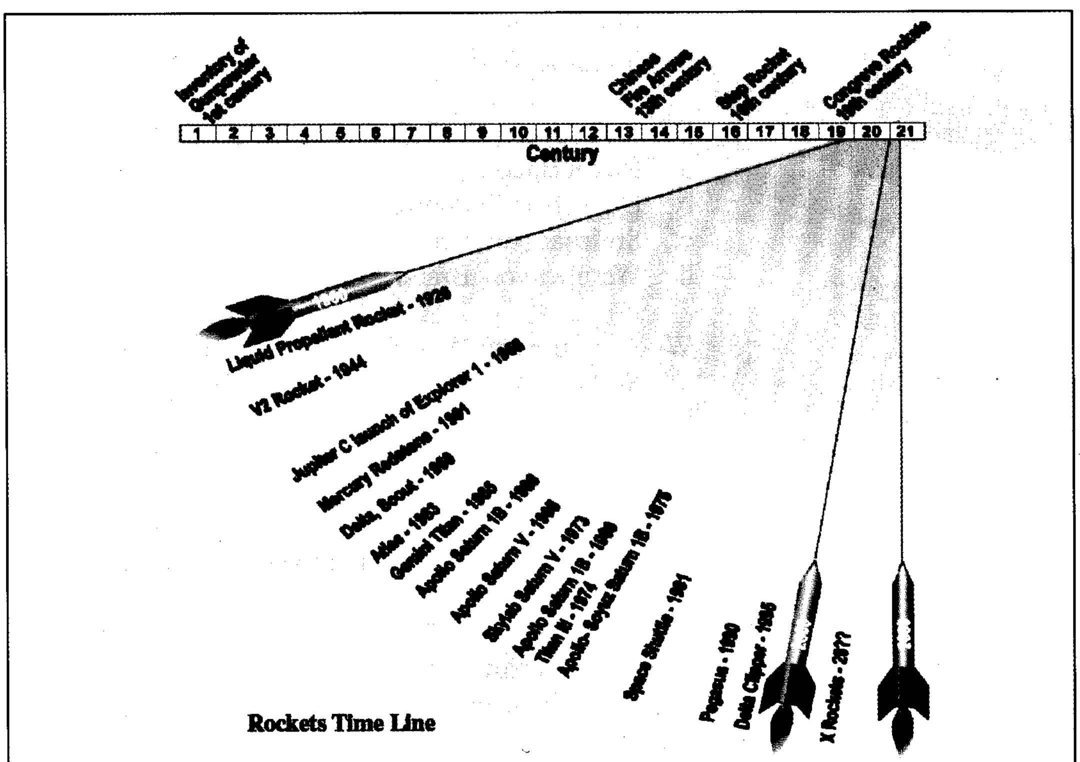


A Space Shuttle Landing

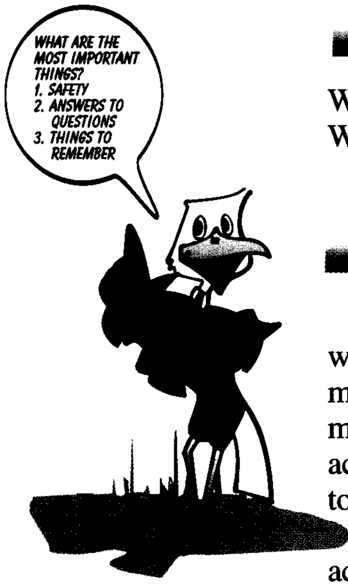
rocket boosters for a safe splashdown in the Atlantic Ocean, where ships recover them. The ***Space Shuttle*** is really a space transportation system used for transporting to space and returning back to Earth.

This section gave a brief account of how rocket launch vehicles were used in the space race. A more detailed account of the US manned space program is contained in module six of Aerospace Dimensions.

Rockets evolved from simple gunpowder devices into giant vehicles capable of traveling into outer space, taking astronauts to the Moon and launching satellites to explore our universe. Without a doubt, rockets have opened the universe to our exploration.



Rockets Time Line



QUESTIONS: Chapter 1

When and where did the history of rockets begin?
Who is the father of modern rocketry?

THINGS TO REMEMBER

Rockets have been a part of history for a long time and have been used as a weapon by many countries. Since early in the 20th century, we have made major strides with the development of rockets. Dr. Goddard, the father of modern rocketry, greatly advanced the study of rockets. One of his major achievements was the liquid-propelled rocket, which was the forerunner of today's rockets.

Space exploration has been in progress for many years. Much has been accomplished since then: a man in orbit around the Earth, a man on the Moon, a space station, and a reusable launch system. Rockets are still sending spacecraft into space to explore the universe.

REVIEW QUESTIONS

1. Whose laws of motion laid the scientific foundation for modern rocketry?
   a. Colonel Congreve
   b. Roger Bacon
   c. Francis Scott Key
   d. Sir Isaac Newton

2. Who is known as the father of modern rocketry?
   a. Roger Bacon
   b. Dr. Robert Goddard
   c. Sir Isaac Newton
   d. Wernher von Braun

3. Who was the first American to orbit the Earth?
   a. Neil Armstrong
   b. John Glenn
   c. Alan Shepard
   d. Chuck Yeager

4. Who was the first American to walk on the Moon?
   a. Neil Armstrong
   b. John Glenn
   c. Alan Shepard
   d. Chuck Yeager

5. What was the name of America's first space station?
   a. *Apollo* I
   b. *Mercury* I
   c. Skylab

2 ROCKET PRINCIPLES

Important Terms

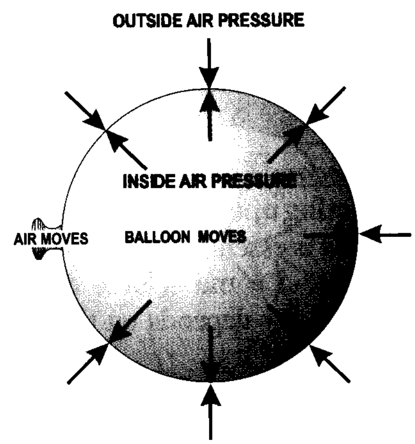
acceleration - the rate of change in velocity with respect to time
inertia - the tendency of an object at rest to stay at rest and an object in motion to stay in motion
Newton's First Law of Motion - a body at rest remains at rest and a body in motion tends to stay in motion at a constant velocity unless acted on by an outside force
Newton's Second Law of Motion - the rate of change in the momentum of a body is proportional to the force acting upon the body and is in the direction of the force
Newton's Third Law of Motion - to every action, there is an equal and opposite reaction
thrust - to force or push , the amount of push used to get the rocket traveling upwards

In this chapter, we will take a brief look at some of the concepts and principles that explain how rockets work, with a particular emphasis on Newton's Laws of Motion. These laws lay the scientific foundation for rockets and aid tremendously in explaining how rockets work.

PRINCIPLES

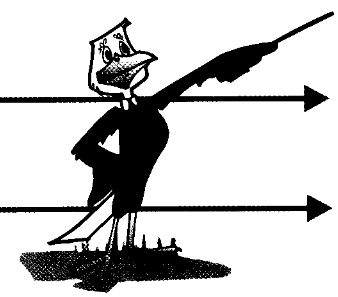
In its simplest form, a rocket is a chamber enclosing a gas under pressure. A small opening at one end of the chamber allows the gas to escape, and thus provides a thrust that propels the rocket in the opposite direction. A good example is a balloon. Use the following activity as a simple illustration of a rocket.

Balloons and rockets actually have a strong similarity. The only significant difference is the way the pressurized gas is produced. With space rockets, the solid or liquid burning propellants produce the gas.



See Activity One - Balloon Rocket
Refer to the Activity Section at the end of the chapter for this activity.

See Activity Two - Rocket Racer
Refer to the Activity Section at the end of the chapter for this activity.



NEWTON'S LAWS OF MOTION

Even though rockets have been around for over 2,000 years, it has only been in the last 300 years that rocket experimenters have had a scientific basis for understanding how they work. This scientific basis came from **Sir Isaac Newton**. Newton stated three important scientific principles that govern the motion of all objects, whether on Earth or in space. Understanding these principles has enabled rocketeers to construct the giant rockets we use today. These principles are known as **Newton's Laws of**

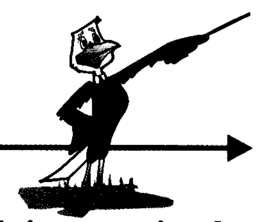
Motion.

***Newton's First Law of Motion*: a body at rest remains at rest and a body in motion tends to stay in motion at a constant velocity unless acted on by an outside force.**

Rest and motion are the opposite of each other. If a ball is sitting on the ground, it is at rest. If it is rolling, it is in motion. If you hold a ball in your hand and keep it still, the ball is at rest. All the time the ball is being held there, it is acted upon by forces. The force of gravity is trying to pull the ball downward, while at the same time your hand is pushing against the ball to hold it up. The forces acting on the ball are balanced. Let the ball go, or move your hand upward, and the forces become unbalanced. The ball then changes from a state of rest to a state of motion.

In rocket flight, forces become balanced and unbalanced all the time. A rocket on the launch pad is balanced. The surface of the pad pushes the rocket up while gravity tries to pull it down. As the engines are ignited, the thrust from the rocket unbalances the forces, and the rocket travels upward. **Thrust** is defined as the amount of push used to get the rocket traveling upwards.

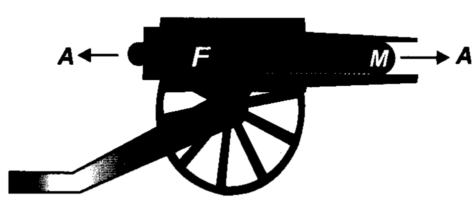
Consider a grocery cart full of groceries that you are pushing down an aisle. Let's pretend there is no friction from the wheels or from the floor. The cart weighs 75 pounds, and you are pushing it at 100 ft/min. What force must you exert on the cart to keep it moving in a straight line at this constant speed? The answer is none. You exerted a force to start it from rest, and you will need to exert a force to stop it, but no force is needed to keep it moving at constant velocity if there is no friction. **Inertia** is the tendency of an object at rest to stay at rest and an object in motion to stay in motion.



See Activity Three - Law of Inertia
Refer to the Activity Section at the end of the chapter for this activity.

***Newton's Second Law of Motion*: the rate of change in the momentum of a body is proportional to the force acting upon the body and is in the direction of the force.**

This law is essentially a mathematical equation. There are three parts: **mass (m), acceleration (a),** and **force (f) - f = ma (force equals mass times acceleration).** The amount of force required to accelerate a body depends on the mass of the body. The more mass, the more force is required to accelerate it.



Acceleration is defined as the rate of change in velocity with respect to time. Use a cannon as an example to help explain. When the cannon is fired, an explosion propels a cannon ball out the open end of the barrel. It flies to its target. At the same time, the cannon itself is pushed backward. The force acting on the cannon and the ball is the same. Since f = ma, if the mass increases, then the acceleration decreases; if the mass decreases, then the acceleration increases.

Apply this principle to a rocket. Replace the mass of the cannon ball with the mass of the gases being ejected out of the rocket engine. Replace the mass of the cannon with the mass of the rocket moving in the other direction. Force is the pressure created by the controlled explosion taking place inside the rocket's engines. That pressure accelerates the gas one way and the rocket the other.

Another example of this law would be a hockey puck sliding over the ice. That puck has a quantity of motion that slowly decreases due to being in contact with the ice, which causes friction.

***Newton's Third Law of Motion*: to every action, there is an equal and opposite reaction.**

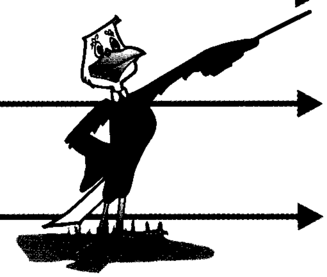
A rocket can lift off from a launch pad only when it expels gas out of its engine. The rocket pushes on the gas, and the gas in turn pushes on the rocket. The example of a skateboard and rider illustrates this point. Imagine the skateboard and rider at rest. The rider jumps off the skateboard. The jumping is called the action. The skateboard responds to that action by traveling some distance in the opposite direction. The skateboard's opposite motion is called the reaction.

With rockets, the action is the expelling of gas out of the engine. The reaction is the movement of the rocket in the opposite direction. To enable a rocket to lift off from the launch pad, the action, or thrust, from the engine must be greater than the weight of the rocket.

Another example is a man walking on level ground pushes against the ground with his feet. The earth also pushes against his feet with an equal and opposite force.

See Activity Four - Two Balloons
Refer to the Activity Section at the end of the chapter for this activity.

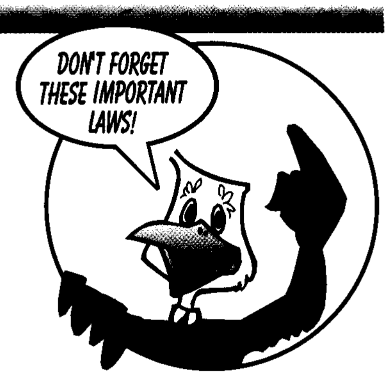
See Activity Five - Roller Skates and Jug
Refer to the Activity Section at the end of the chapter for this activity.



See Activity Six - Antacid Tablet Race - Experiment 1
Refer to the Activity Section at the end of the chapter for this activity.

See Activity Seven - Newton Car
Refer to the Activity Section at the end of the chapter for this activity.

THINGS TO REMEMBER



Sir Isaac Newton gave rocket development a scientific foundation with the discovery of his laws of motion. These laws are basic laws of science which have wide applicability.

- Newton's First Law - a body at rest remains at rest and a body in motion tends to stay in motion, unless acted on by an outside force.
- Newton's Second Law- force is equal to mass times acceleration and forces acceleration in the same direction.
- Newton's Third Law - for every action there is an equal and opposite reaction.

Don't forget to take a look at the Activity Section. You will find activities that demonstrate Newton's Laws, and other activities that will reinforce what you have studied in this chapter. **Please be safe** when performing these activities.

REVIEW QUESTIONS

1. The amount of push needed to get a rocket traveling upward is called
   a. acceleration.
   b. thrust.
   c. velocity.
   d. speed.

2. A body at rest remaining at rest is part of Newton's ______ Law of Motion.
   a. First
   b. Second
   c. Third
   d. Fourth

3. For every action there is an equal and opposite reaction is Newton's ______ Law of Motion.
   a. First
   b. Second
   c. Third
   d. Fourth

4. The rate of change in the momentum of a body is proportional to the force acting upon the body and in the direction of the body is Newton's ______ Law of Motion.
   a. First
   b. Second
   c. Third
   d. Fourth

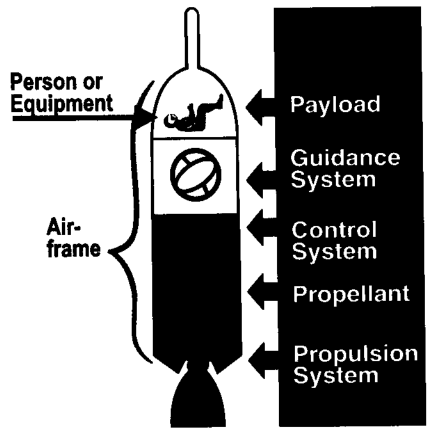
3 ROCKET SYSTEMS AND CONTROLS

Important Terms

airframe - the shape of the rocket
control system - steers the rocket and keeps it stable
guidance system - gets the rocket to its destination; the brain of the rocket
payload - what the rocket is carrying
propulsion - everything associated with propelling the rocket
thrust - to force or push; the amount of push used to get a rocket traveling upwards

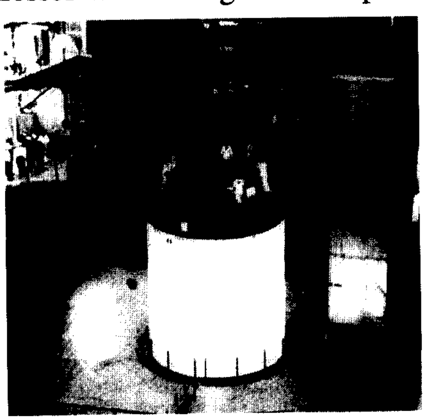
ROCKET SYSTEMS

Modern rockets consist of four major systems: **airframe, guidance, control** and **propulsion.** These four systems work together to deliver the payload. The **payload** is defined as whatever the rocket is carrying. For instance, the payload of a military rocket might be explosives, while the payload of a civilian rocket might be satellites. The astronauts and their data are also part of the payload.



Major Systems of Rockets

The **airframe** provides the shape of the rocket and all of the other systems are contained within it. The airframe must be light-weight, yet structurally strong. It must withstand heat, stress and a lot of vibration. The primary objective in the design and construction of an airframe is to build a structure that will withstand all anticipated stresses while using the least possible weight. For example, the airframe of the Atlas rocket is thinner than a dime. When the Atlas has no fuel aboard, it must be pressurized to keep it from collapsing. The airframe is the skin of the rocket and serves as the wall of the propellant tanks. This eliminates the need for separate internal tanks and saves in weight too.


The Guidance System

The **guidance** system is the "brain" of a rocket. It is responsible for getting the rocket and its payload to its destination. In a military missile, the guidance system delivers the warhead to its target. In a civilian rocket, the guidance system is responsible for delivering the spacecraft to its proper orbit or destination.

The guidance system is small compared to the rest of the rocket. This photo gives you an idea of its actual size as it sits on top of the third stage of a rocket. It is a self-contained electronic unit with a computer. The computer is programmed to guide the rocket on a desired trajectory. There is also a radio link between the rocket's mission controllers and its guidance system. This allows changes to be made if necessary.

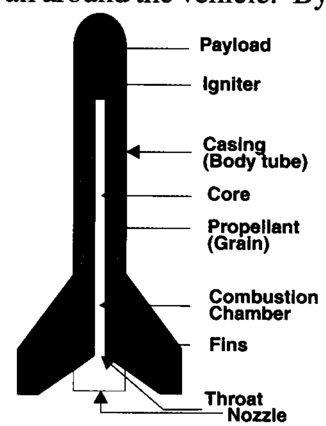
The **control** system takes the information from the guidance system and steers the rocket to its destination. The control system also keeps the rocket stable. The control system is actually several controls that work to stabilize and steer the rocket. These controls allow for changes to be made during the rocket's flight.

Vanes, movable fins, gimbaled nozzles and attitude-control rockets are a few examples of controls that can help steer or stabilize a rocket. Vanes are like small fins that are placed inside the exhaust of the rocket engine. Tilting the vanes deflects the exhaust and changes the direction the rocket is going.

A gimbaled nozzle is one that sways while the exhaust passes through it. This also changes a rocket's direction. A rocket's movable fins can be tilted to change the rocket's direction. The most commonly used are the attitude-control rockets. Small clusters of engines are mounted all around the vehicle. By firing the right combination of these small rockets, the vehicle can be turned in any direction.

The **propulsion** system consists of everything directly associated with propelling the rocket. This includes the propellant used, the containers for the propellant and the engine. The propellant doesn't mean just the fuel, but includes both the fuel and the oxidizer. The fuel is the chemical the rocket burns and the oxidizer (oxygen) must be present. Rockets must carry oxygen with them because there is none in space.

There are two rocket propellants, liquid or solid. The solid propellant is carried in the combustion chamber and is much simpler than the liquid propellant. The solid propellant is illustrated in the picture on the right. The fuel is usually a mixture of hydrogen compounds and carbon, and the oxidizer is made up of oxygen compounds.

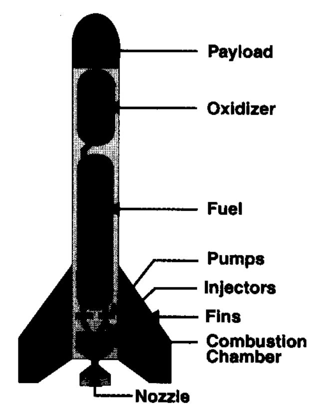


Solid Fuel Propulsion System

The liquid propellant is much more complicated. Remember that solid rocket propellants were used for 700 years before the liquid propellant. Liquid propellants are carried in compartments separate from the combustion chamber, one for the fuel and one for the oxidizer. The liquid propellant is usually kerosene or liquid hydrogen; the oxidizer is usually liquid oxygen.

The liquid propellant is what is commonly used today. It is heavier than a solid propellant, but easier to control.

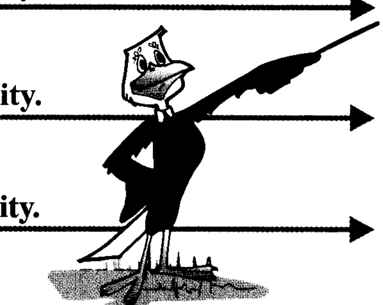
Most rockets today operate with either solid or liquid propellants. The liquid propellant is heavier than a solid propellant, but easier to control.



Liquid Fuel Propulsion System

See Activity One - 3-2-1 POP
Refer to the Activity Section at the end of the chapter for this activity.

See Activity Two - Bottle Rocket
Refer to the Activity Section at the end of the chapter for this activity.



See Activity Three - Altitude Tracking
Refer to the Activity Section at the end of the chapter for this activity.

See Activity Four - Goddard Rocket
Refer to the Activity Section at the end of the chapter for this activity.

THINGS TO REMEMBER

1. Modern rockets consist of four major systems: **airframe, guidance, control** and **propulsion.**
2. Whatever the rocket is carrying is called its **payload.**
3. The **liquid propellant** is the most commonly used propellant today. Most rockets today operate with either solid or liquid propellants.

Be sure to perform these activities. They are fun and will help demonstrate some of the important information you have learned in this volume. **BE CAREFUL!**

REVIEW QUESTIONS

1. Which of the four major rocket systems provides the shape of the rocket?
   a. Airframe
   b. Guidance
   c. Payload
   d. Propulsion

2. Whatever the rocket is carrying is called the __________.
   a. airframe
   b. control
   c. payload
   d. propulsion

3. Which of the following systems is the brain of the rocket?
   a. Airframe
   b. Guidance
   c. Payload
   d. Propulsion

4. What system steers the rocket and keeps it stable?
   a. Control
   b. Guidance
   c. Propulsion
   d. Payload